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A New Species of the Genus *Feirana* (Amphibia: Anura: Dicroglossidae) from the Western Qinling Mountains of China

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Abstract A new species, *Feirana kangxianensis* sp. nov., is described from the western Qinling Mountains in Gansu, China. Both morphological and molecular data support its validity. The new species is characterized by: (1) presence of keratinized nuptial spines on the thenar region of the hands in males of the new species, in contrast to *F. taihangnica* and *F. quadranus*; (2) of females, the ratios of UEW, INS, NSD and IPTL to SVL of *F. kangxianensis* were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$), while the ratio of IOS to SVL of the new species was significantly larger than that of the latter two species ($P < 0.05$); and (3) of males, the ratios of INS, NSD, IPTW to SVL of the new species were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$), while the ratio of HL to SVL of the former was significantly larger than that of the latter, and the ratio of HW to SVL of *F. kangxianensis* was significantly larger than that of *F. taihangnica* but less than that of *F. quadranus*, the ratio of OPTL to SVL of *F. kangxianensis* was significantly less than that of *F. taihangnica* but larger than that of *F. quadranus* ($P < 0.05$). The three species of *Feirana* can be easily identified and significantly differ from each other by the canonical discriminant analyses with high correct classification (>92%). Concurrently, based on partial mitochondrial ND2 gene sequences, the result of the molecular phylogenetic analyses of the *Feirana* indicates that the *F. kangxianensis* is sister to *F. taihangnica*.

Keywords *Feirana kangxianensis* sp. nov., Dicroglossidae, Kangxian, Western China

1. Introduction

The genus *Feirana* contained two species and was widely distributed in central China (Fei *et al*., 2009; 2010a; 2010b). The classification and species content of this group have been controversial. The *Rana quadranus*, as the type species of the genus *Feirana*, was named by Liu *et al*. (1960) based on the types collected from Wushan in Chongqin. Dubois (1987) transferred the species to the subgenus *Rana* (*Paa*) Dubois, 1975, and then Fei *et al.* (1990) assigned it in the newly created subgenus *Paa* (*Quadrana*), which contained only this species at that time. The new subgenus was proposed to replace the nomen *Quadrana* which had been preoccupied in zoology with the nomen *Feirana* by Dubois (1992), and this was followed by Fei (1999). Li *et al*. (2000) first recorded *Paa quadrana* from Kangxian in Southern Gansu. Subsequently, two other cryptic species were recognized in this taxon: *Paa* (*Feirana*) *yei* Chen, Qu and Jiang, 2002, and *Paa* (*Feirana*) *taihangnicus* Chen and Jiang, 2002. Fei *et al.* (2005) elevated *Paa* (*Feirana*) to the generic level as *Feirana*, including the above three species. However, the results of molecular systematics of Jiang *et al.* (2005) indicated that the species *Feirana yei* was not a member of this genus and referred it to the genus *Quasipaa*. This was supported by Ohler and Dubois (2006) based on morphological data and Che *et al.* (2009) based on molecular evidence. Then, Jiang *et al.* (2006) erected the monotypic genus *Yerana* based on its specialized morphological and molecular characters. Jiang *et al.* (2005) published simultaneously the justified amendment of *taihangnica* for the incorrect original spelling *taihangnicus*. Che *et al.* (2010) and Wang *et al.* (2009) showed that the two species *F. quadranus* and *F.*

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taihangnica were clustered together as a monophyletic group, supporting that the genus *Feirana* contained the two species, although Chen *et al.* (2005), Frost *et al.* (2006), and Che *et al.* (2009, 2010) referred these two species to the catch-all genus *Nanorana* Günther, 1896, and Ohler and Dubois (2006) referred the species *F. taihangnica* to the subgenus *Paa* of the genus *Chaparana* Bourret, 1939, and the species *F. quadranus* to the subgenus *Feirana* of the genus *Gynandropaa* Dubois, 1992. For reasons detailed in the discussion of Wang *et al*. (2009), we argue for retaining these two species in the genus *Feirana*, for the time being.

Based on morphometirc analyses, the populations of *F. quadranus* from the Funiu Mountains in Henan, and the southern Taihang Mountains in Shanxi and Henan, China should be *F. taihangnica* (Wang *et al*., 2007). They also suggested that some populations from the Qinling Mountains might be a new subspecies or species. Using the molecular phylogenetic analyses on partial 12S and 16S genes and complete ND2 gene of the populations of *Feirana*, Wang *et al.* (2009) showed that the Kangxian population, located in the western Qinling Mountains in Gansu, China, was the basal lineage of the *F. taihangnica* and diverged deeply from the other lineages across the species' recognized geographic distribution range. These results indicated that the Kangxian population of *F. taihangnica* in the western Qinling Mountains might be an independently evolving species. In 2010, we collected additional specimens in the Kangxian County, Gansu, China and found black keratinized nuptial spines occurring on the thumb of males. This is a distinct character, as the spines are absent on the thumb of *F. taihangnica* and *F. quadranus*, further supporting that the Kangxian population represents a new form, which is described as *Feirana kangxianensis* sp. nov. in this study.

2. Material and Methods

2.1 Morphological analyses A total of 571 adult specimens from 14 populations of the *Feirana*, were examined (Table 1, Figure 1, Appendix), of which 376 specimens were used by Wang *et al.* (2007). Following Fei *et al.* (2009), 28 measurements of the specimens were measured [The measurements of the 376 specimens made by Wang *et al.* (2007) were used in this study] to the nearest to 0.02 mm using dial calipers, including SVL = snout–vent length, HL = head length, HW = head width, VRL = length of vomerine ridge, SL = snout length, ED = diameter of eye, UEW = width of upper eyelid, IOS = interorbital space, INS = internasal space, NSD = distance between nostril and snout, NED = distance between nostril and eye, PED = distance between posterior corners of eyes, AED = distance between anterior corners of eyes, TD = diameter of tympanum (longitudinal direction), TED = distance from anterior edge of tympanum to posterior corner of the eye, LAHL = length of lower arm and hand, HaL = hand length, TL = tibia length, TW = tibia width, TFL = length of foot and leg length, FL = foot length, IPTL = length of inner metacarpal tubercle, IPTW = width of inner metacarpal tubercle, OPTL = length of outer metacarpal tubercle, OPTW = width of outer metacarpal tubercle, IML = length of inner metatarsal tubercle, IMW = width of inner metatarsal tubercle, TiL = Thigh length. Concurrently, some morphometrical characters of 20 tadpoles collected from Kangxian County were measured (Table 7). These specimens were deposited at the Chengdu

Table 1 All specimens from 14 populations of *Feirana* used for morphological analyses in this study

Species	Population code	Locality	Numbers of females	Numbers of males
F. kangxianensis	1*	Kangxian County, Gansu	45	55
F. taihangnica	2	Zhouzhi County, Shaanxi	49	45
	3	Taibai County, Shaanxi	15	20
	4	Zhashui County, Shaanxi	5	3
	5	Ningshan County, Shaanxi	4	6
	6	Qinshui County, Shanxi	11	11
	7	Luanchuan County, Henan	10	10
	8*	Jiyuan County, Henan	9	10
F. quadranus	9*	Wushan County, Chongqing	42	70
	10	Liangdang County, Gansu	4	6
	11	Lichuan County, Hubei	53	54
	12	Anxian County, Sichuan	7	8
	13	Zhashui County, Shaanxi	9	5
	14	Ningshan County, Shaanxi	2	3

* means that the population was sampled from the type locality of the species.

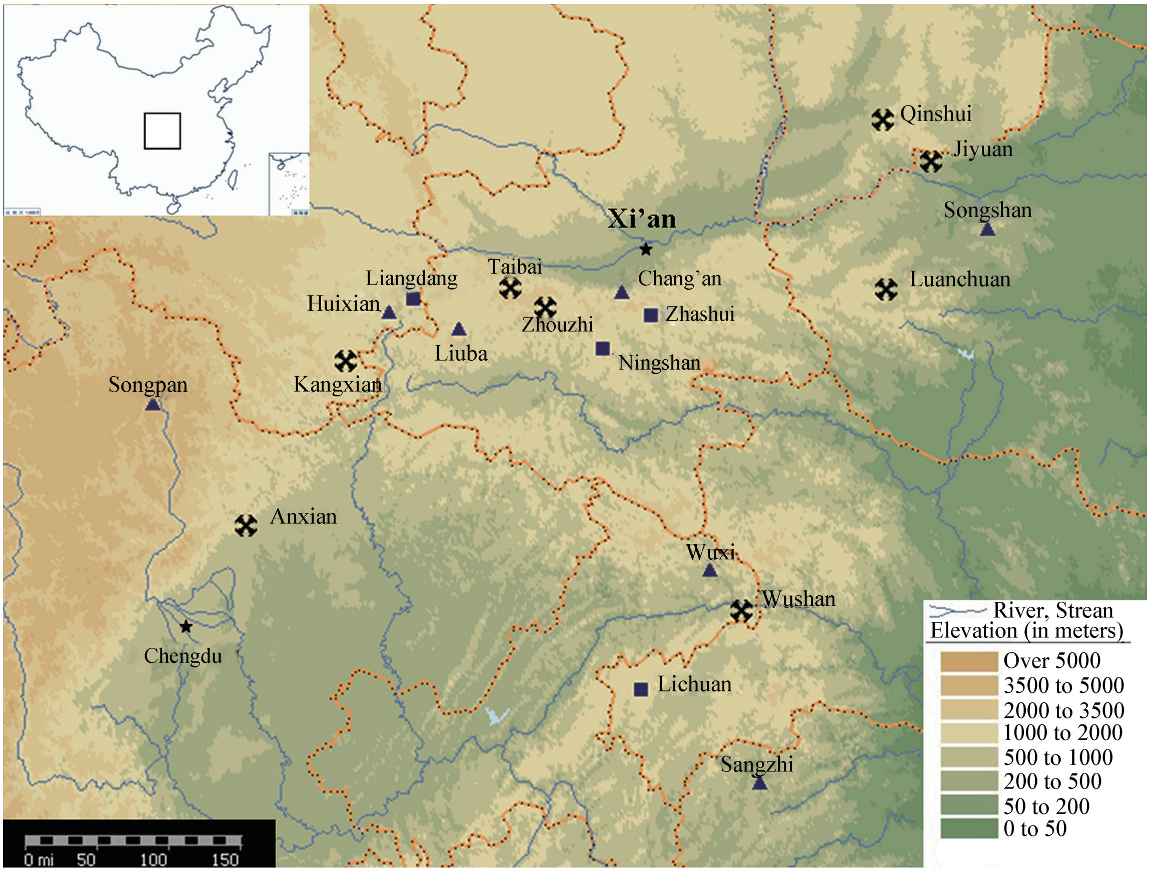

Figure 1 Sampled sites of *Feirana* in this study. Blue triangle: Sampling sites only for molecular analyses; Blue square: Sampling sites only for morphological analyses; Black diagonal cross: Sampling sites for molecular and morphological research.

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In order to reduce the impact of allometry, we used the correct value from the ratio of each measurement to SVL x 100 for the following morphometric analyses. Mann–Whitney U test was used to test the difference between male and female groups on each measurement (Geroge and Mallery, 2005). We compared SVL and other characters with correct value among the three species of the *Feirana* using the least significant difference (LSD) test of the multiple comparisons (Geroge and Mallery, 2005). In the multivariate analyses, we used log–transformed correct values as input variables. The canonical discriminant analyses (CDA; Geroge and Mallery, 2005) were used to identify individuals into different species based on 27 characters. In CDA, the ratio (P1) of the number of individuals by correctly classified to the number of original memberships of each group and the ratio (P2) of the number of individuals by incorrectly classified to the number of original memberships of each group were calculated; and then the average correct classification was calculated with the formula,

$$Z(\%) = \sum_{i}^{k} Ai \,/ \sum_{i}^{k} Bi \times 100$$

where Ai means the individuals correctly classified in the population i, Bi means the total size of this population, and k is equal to the number of populations. All analyses were conducted using Software SPSS 14.0 (SPSS 2005).

2.2 Molecular systematics analyses

2.2.1 Sampling We collected nine samples from the type locality (Kangxian County, Gansu, China) of the new species, *F. kangxianensis*, and eight samples of *F. taihangnica* from four populations (Table 2, Figure 1), and sequenced their partial ND2 gene. In addition, we downloaded ND2 sequences of two samples of *F. kangxianensis*, four of *F. taihangnica* and six of *F. quadranus* (Table 2) for molecular phylogenetic analyses. One sample of *Nanorana pleskei* was used as outgroup according to Jiang *et al.* (2005), Che *et al.* (2009) and Wang *et al.* (2009), and its ND2 sequence was also retrieved from GenBank (Table 2). All the specimens collected in this work were euthanized, sampled for muscle tissue (stored in 95% ethanol) and subsequently fixed in 10% buffered formalin. Voucher specimens (Table

Table 2 Samples used in phylogenetic analyses in this study, with species and sample numbers, voucher numbers, sampling localities, coordinates, and GenBank accession numbers.

Species	Sample No.	Voucher No.	Locality	Coordinates	GenBank accession No.
F. kangxianensis	F1	CIB 2010091104	Luojiadi, Douba, Kangxian County, Gansu	33.1414°N, 105.7151°E	JN016863
	F2	CIB 2010091322	Yangba, Kangxian County, Gansu	33.0692°N, 105.7756°E	JN016864
	F3	CIB 2010091323	Yangba, Kangxian County, Gansu	33.0692°N, 105.7756°E	JN016865
	F4	CiB 2010091324	Yangba, Kangxian County, Gansu	33.0692°N, 105.7756°E	JN016866
	F5	CIB 2010091110	Liujiaba, Douba, Kangxian County, Gansu	33.1892°N, 105.3674°E	JN016867
	F6	CIB 2010091105	Luojiadi, Douba, Kangxian County, Gansu	33.1414°N, 105.7151°E	JN016868
	F7	CIB 2010091109	Liujiaba, Douba, Kangxian County, Gansu	33.1892°N, 105.3674°E	JN016869
	F8	CIB 2010091103	Luojiadi, Douba, Kangxian County, Gansu	33.1414°N, 105.7151°E	JN016870
	F9	CIB 2010091108	Liujiaba, Douba, Kangxian County, Gansu	33.1892°N, 105.3674°E	JN016871
	F10	CIB Kangxian01	Douba, Kangxian County, Gansu	33.2804°N, 105.4367°E	GQ225989*
	F11	CIB Kangxian02	Douba, Kangxian County, Gansu	33.2804°N, 105.4367°E	GQ225990*
F. taihangnica	F12	CIB 2010081105	Zhouzhi County, Shaanxi	33.8100°N, 107.7138°E	JN016876
	F13	CIB 2010080402	Chang'an County, Shaanxi	33.9838°N, 108.8270°E	JN016877
	F14	CIB 2010081106	Zhouzhi County, Shaanxi	33.8100°N, 107.7138°E	JN016878
	F15	CIB 2010080401	Chang'an County, Shaanxi	34.0325°N, 108.8094°E	JN016879
	F16	CIB WB2010042502	Huangjianshu, Jiyuan City, Henan	35.2649°N, 112.0903°E	JN016872
	F17	CIB 20060320	Qinshui County, Shanxi	35.4302°N, 112.0150°E	GQ225999*
	F18	CIB WB2010042501	Huangjianshu, Jiyuan City, Henan	35.2649°N, 112.0902°E	JN016873
	F19	CIB 20060325	Qinshui County, Shanxi	35.4302°N, 112.0184°E	GQ225998*
	F20	CIB 20070485	Songshan County, Henan	33.9305°N, 112.2176°E	GQ226001*
	F21	CIB 20060349	Luanchuan County, Henan	33.7311°N, 112.2963°E	GQ226003*
	F22	CIB Taibai1	Taibai County, Shaanxi	34.0967°N, 107.6476°E	JN016874
	F23	CIB Taibai2	Taibai County, Shaanxi	34.0490°N, 107.5985°E	JN016875
F. quadranus	F24	CIB 20060387	Wushan County, Chongqing	31.3721°N, 109.9074°E	GQ225954*
	F25	CIB Wanzhou34	Wuxi County, Chongqing	31.4804°N, 109.9026°E	GQ225955*
	F26	CIB Liuba03	Liuba County, Shaanxi	33.7031°N, 107.0848°E	GQ225942*
	F27	CIB B20010018	Shangzhi County, Hunan	29.6346°N, 109.9232°E	GQ225958*
	F28	CIB 20060644	Anaxian County, Sichuan	31.6316°N, 104.1856°E	GQ225933*
	F29	CIB Huixian01	Huixian County, Gansu	33.8964°N, 105.8702°E	GQ225937*
Nanorana pleskei		CIB F97034	Songpan County, Sichuan	32.6463°N, 103.5885° E	GQ225879*

* means that the sequence was retrieved from Wang *et al.* (2009).

2) were preserved in the CIB.

2.2.2 DNA sequencing Total genomic DNA was extracted using a standard phenol–chloroform extraction procedure (Hillis *et al.*, 1996). The polymerase chain reaction (PCR) was used to amplify ND2 gene with primers Pmet and Ptrp (Wang *et al.*, 2009). Amplification was performed using a PTC–200 thermocycler with the following conditions: initial denaturation at 94 °C for 4 min followed by 35 cycles of: denaturation at 94 °C for 40 s, annealing at 53 °C for 40 s, and extension at 72 °C for 70 s, with a final extension at 72 °C for 8 min. Negative controls were run for all amplifications. The amplifications of ND2 gene were cleaned using the TIANgel Midi Kit (TIANGEN). The ND2 regions were sequenced in plus direction using primer Pmet. Sequencing was performed on ABI 3730 sequencer, and all new sequences were deposited in GenBank (The accession numbers are presented in Table 2).

2.2.3 Phylogenetic analyses All sequences were aligned using Clustal X 1.83 (Thompson *et al.*, 1997) with the default settings. Maximum parsimony (MP), maximum likelihood (ML) and Bayesian inference (BI) analyses were used to reconstruct the phylogenetic relationships. MP analysis was performed using PAUP 4.0b10 (Sworfford, 2002), Heuristic MP searches were executed in 1,000 replicates with all characters unordered and equally weighted, and using tree bisection reconnection (TBR) branch swapping. Under the Corrected Akaike Information Criterion (AICc; Hurvich and Tsai, 1989), the TIM2+I model was selected as the best–fit model for our data set by likelihood ratio tests implemented in jModelTest (Posada, 2008; Guindon and Gascuel, 2003). Under this model, ML analysis was performed using the program PhyML version 3.0 (Guindon and Gascuel, 2003). We set the proportion of invariant sites and the shape of the Gamma distribution in PHYML as 0.6590 and 0 estimated by jModelTest, respectively. The base frequency and ratio of transitions/transversions were optimized by the maximum likelihood criterion in PhyML. To assess confidences of branches in MP and ML trees, we used non-parametric bootstrapping with heuristic searches of 1,000 replicates (Felsenstein, 1985; Felsenstein and Kishino, 1993; Hedges, 1992). Tree topologies with bootstrap values (bs) 70% or greater were regarded as sufficiently resolved (Huelsenbeck and Hillis, 1993). Bayesian analyses using the Markov-chain Monte-Carlo technique (MCMC) were conducted for the combined data by using MrBayes 3.0b4 (Ronquist and Huelsenbeck, 2003). We used the TrN+I model under the Bayesian Information Criterion (BIC) estimated in jModeltest, initiated two dependent runs, each with four simultaneous MCMC chains, for 1×10^7 generations and sampled trees every 1,000 generations. We determined the burn-in period graphically by using the parameter log-likelihood scores, which were found to stabilize after 2.5×10^6 generations within and among the four independent analyses. The first 2,500 trees were discarded as burn-in, and from the remaining trees we obtained a 50% Bayesian consensus tree and posterior probability (pp) values for nodes. Posterior probabilities 95% or greater were considered to be significantly strong support (Leaché and Reeder, 2002; Parra-Olea *et al.*, 2004).

2.2.4 Genetic distance analyses Based on our ND2 dataset, we calculated the TN93 genetic distance (Tamura and Nei, 1993) of the interclades and intraclades in phylogenetic trees. All genetic distances were calculated using MEGA 4.0 (Kamur *et al.*, 2008).

3. Results

3.1 Morphological analyses The keratinized nuptial spines were found on the thumb of males of the Kangxian population (55 males, previously included in *F. taihangnica*; Figure 4 E, F), but not on the thumb of the other populations of *F. taihangnica* (105 males) and *F. quadranus* (146 males).

Multiple comparisons showed that the ratios of UEW, INS, NSD and IPTL to SVL of the females of *F. kangxianensis* were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$), while the ratio of IOS to SVL of the females of *F. kangxianensis* was significantly larger than that of *F. taihangnica* and *F. quadranus* ($P < 0.05$; Table 3). Similarly, the ratios of INS, NSD, IPTW to SVL of the males of *F. kangxianensis* were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$), while the ratio of HL to SVL of the males of *F. kangxianensis* was significantly larger than those of *F. taihangnica* and *F. quadranus*, and the

Table 3 The measurements with significant differences between the male and female groups of *F. kangxianensis*, *F. taihangnica* and *F. quadranus*

Sex	Ratio	*F. kangxianensis*	*F. quadranus*	*F. taihangnica*
Male	HL/SVL	32.39±6.49 (22.74−47.00)	29.14±6.65 (17.56−53.55)	26.18±5.76 (14.30−44.05)
	HW/SVL	37.42±8.21 (24.71−56.60)	40.56±8.71 (24.09−70.93)	34.47±8.00 (21.41−57.71)
	INS/SVL	8.88±1.25 (6.60−11.30)	10.07±2.21 (5.60−17.58)	9.95±2.25 (6.31−17.29)
	NSD/SVL	7.88±1.46 (3.78−11.16)	9.75±2.51 (5.21−17.34)	9.53±2.39 (5.66−17.87)
	IPTW/SVL	3.47±0.78 (1.24−5.26)	4.54±1.26 (2.25−8.53)	4.09±1.26 (1.82−8.41)
	OPTL/SVL	4.92±0.87 (3.79−7.13)	4.46±1.66 (3.45−11.85)	5.42±1.57 (2.46−11.02)
Female	UEW/SVL	8.28±1.85 (5.26−12.14)	10.78±2.48 (5.82−16.88)	9.28±2.35 (4.60−15.25)
	IOS/SVL	6.99±1.69 (4.23−11.87)	6.46±1.42 (2.82−11.32)	5.56±1.34 (3.26−10.71)
	INS/SVL	9.48±1.50 (7.03−13.23)	10.91±2.25 (6.15−16.84)	10.50±2.41 (5.99−15.86)
	NSD/SVL	8.37±1.46 (5.91−11.73)	10.45±2.71 (4.70−18.05)	10.10±2.42 (5.38−15.59)
	IPTL/SVL	3.63±0.63 (2.59−5.44)	4.68±1.40 (1.66−8.22)	4.37±1.27 (2.04−7.50)

The abbreviations (see the sections of Materials and Methods. The same below.) show the ratio of each measurement to SVL timing 100. Mean ± SD (minimum−maximum).

ratio of HW to SVL of *F. kangxianensis* was significantly larger than that of *F. taihangnica* but less than that of *F. quadranus*, the ratio of OPTL to SVL of *F. kangxianensis* was significantly less than that of *F. taihangnica* but larger than that of *F. quadranus* ($P < 0.05$; Table 3).

The canonical discriminant analyses showed that the three species mostly clustered separated from each other either in the male or female group (Figure 2). For the male group, the eigenvalues of functions 1 and 2 were 2.720 and 1.951, accounting for 58.2% and 41.8% of the whole eigenvalue, respectively, and their cumulation reached 100%. The eigenvalues of the first two functions in the female group were 3.391 and 1.825, accounting for 65.0% and 35.0% of the whole eigenvalue, respectively, and their cumulation also reached 100%. Thus, the discrimination effects of the first two functions in the two sexual groups were significant and could represent all variables. The value Z of the male group was 95.1%, and that of the female group was 94.3%. The P1 of each species was over 92% (Table 4) in both the male and female groups, suggesting the discrimination effects were perfect. The absolute values of standardized canonical discriminant function coefficient (Table 5) indicated that in the male group, the biggest discriminating power of function 1 was HW, and that of function 2 was also HW, while in the female group, the biggest one of function 1 was HW, and that of function 2 was TL.

3.2 Molecular analyses

3.2.1 Phylogenetic analyses Aligned ND2 sequences of all 30 samples yielded a total 759 bps, in which 212 bps were variable including 159 parsimony informative sites. In MP analyses, four equally most parsimonious trees were obtained (299 steps; consistency index [CI] =

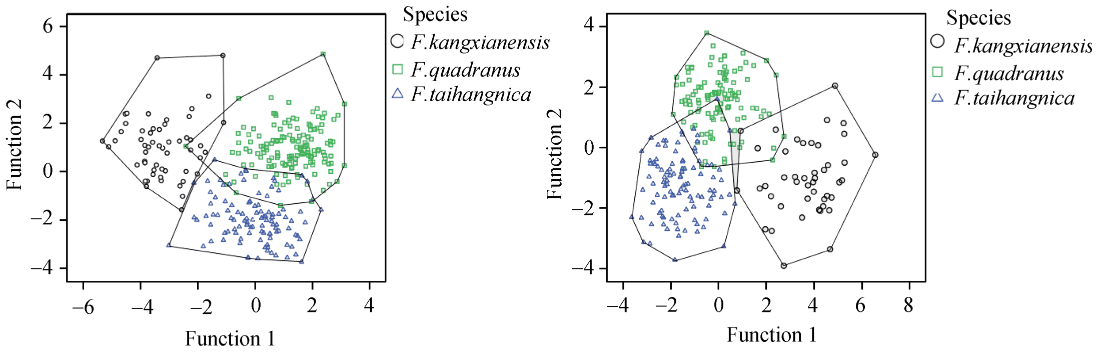

Figure 2 Distribution of the three *Feirana* species on functions 1 and 2 in the canonical discriminant analyses. The left is for the male group and the right for the female group.

Table 4 The statistic results of the canonical discriminant analyses. P1 and P2 were defined in the method

Species	Sex group	*F. kangxianensis*	*F. taihangnica*	*F. quadranus*
The numbers of individuals by correctly classified / P1	Male	55/100	97/92.4	139/95.2
	Female	43/95.6	99/96.1	108/92.3
Incorrectly identified species: Number of individuals by incorrectly classified / P2	Male		*F. kangxianensis*: 2/1.9 *F. quadranus*: 6/5.7	*F. kangxianensis*: 1/0.7 *F. taihangnica*: 6/4.1
	Female	*F. taihangnica*: 1/2.2 *F. quadranus*: 1/2.2	*F. quadranus*: 4/3.9	*F. kangxianensis*: 3/2.6 *F. taihangnica*: 6/5.1

Table 5 The first five measurements of the male and female groups with larger absolute values of standardized canonical discriminant function coefficient on functions 1 and 2

Male group				Female group			
Function 1		Function 2		Function 1		Function 2	
HW	−2.404	HW	1.693	HW	3.249	TL	2.126
AED	1.565	INS	−1.548	TFL	−2.181	FL	−2.118
FL	1.217	FL	−1.163	IML	1.277	TiL	−1.786
TFL	0.99	TL	0.827	UEW	−0.94	LAHL	1.61
HL	0.969	IML	0.781	FL	−0.934	ED	1.301

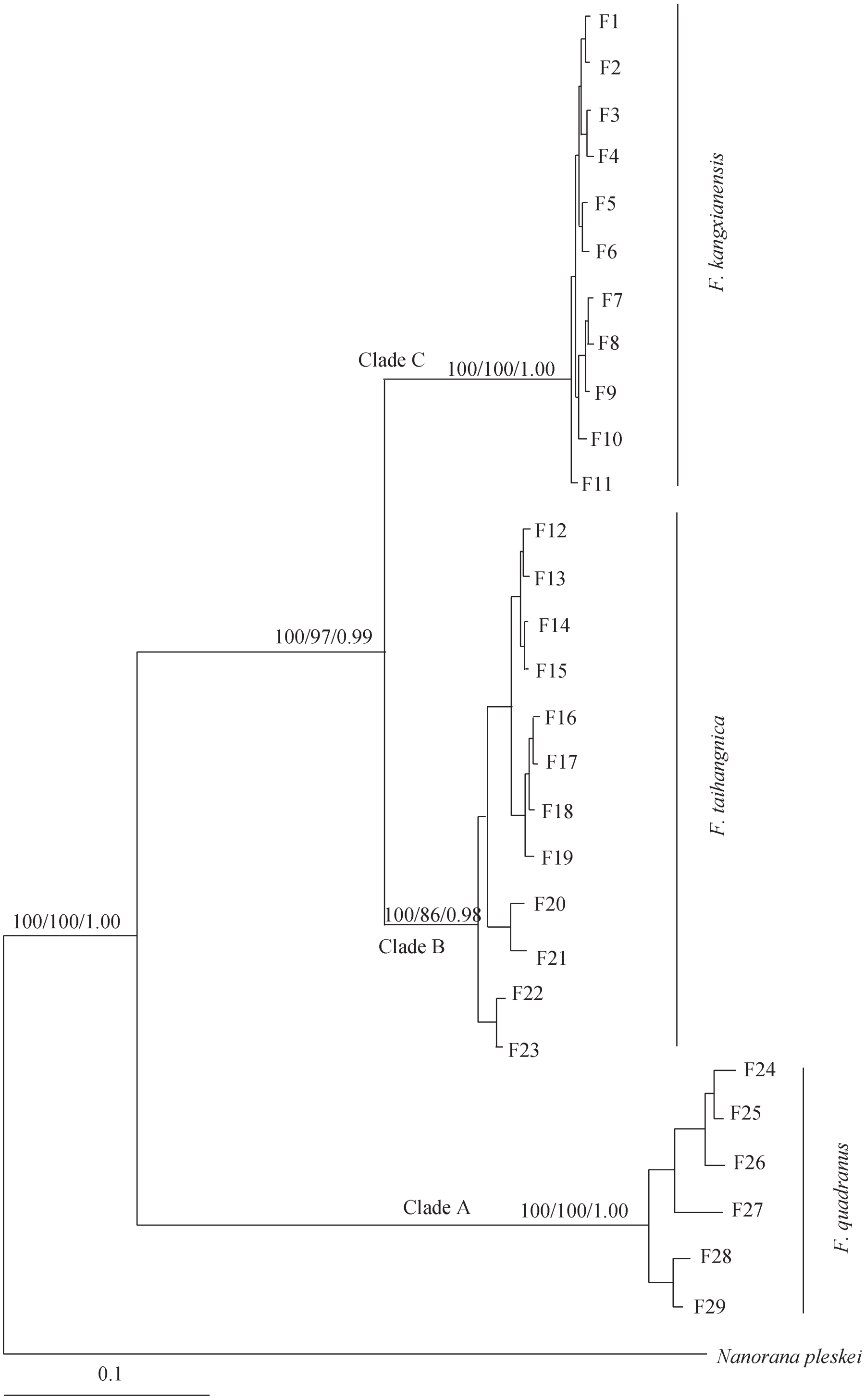

Figure 3 Maximum likelihood (ML) tree based on partial mitochondrial ND2 gene for 29 samples of *Feirana* and one outgroup *Nanorana pleskei*. Sample numbers F1 - F29 are shown in Table 2. The numbers above main branches represent bootstrap supports for maximum parsimony (MP) and ML trees, and Bayesian posterior probabilities for BI tree.

0.7439; retention index [RI] = 0.9462). In ML analyses, the mean –lnL score for ML tree was 2,370.5412.

Our trees were essentially in the same topologies and differed only in few associations at poorly supported nodes. They strongly supported the monophyly of *Feirana* (All supports are 100%; Figure 3). In *Feirana*, three deeply diverged clades (Clade A, B and C; Figure 3) were recognized. Clade A with all 100% supports corresponded to *F. quadranus* firstly diverged (all supports > 95%). Clade B with strong supports (MP/ML/BI: 100/86/0.98)

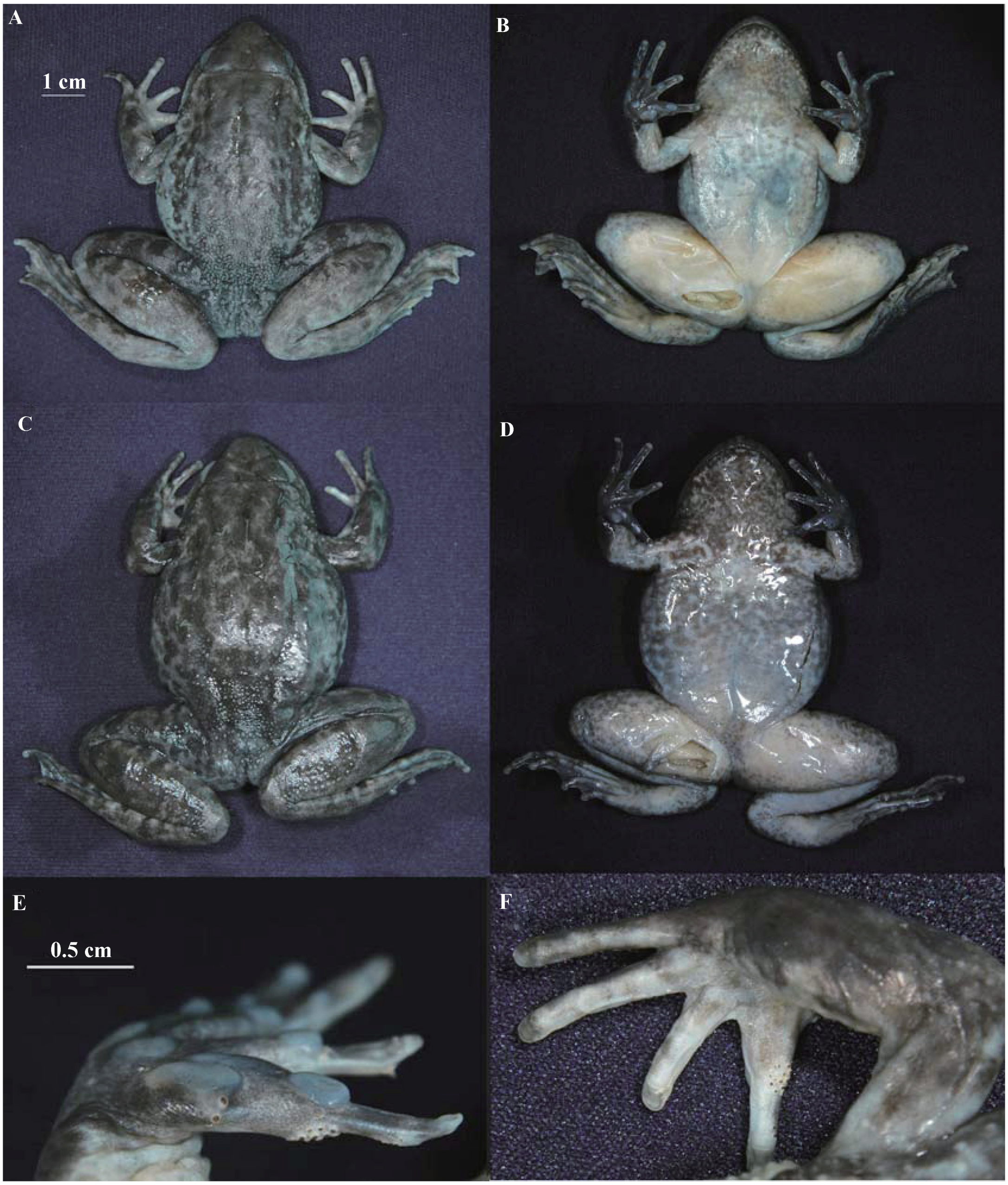

Figure 4 *Feirana kangxianensis* sp. nov. The dorsal view (A) and ventral view (B) of the holotype (CIB 2010091137), and the dorsal view (C) and ventral view (D) of the allotype (CIB 2010091146). The nuptial spines on the thumb of the holotype are shown in E and F

corresponded to *F. taihangnica* including the populations from the region covering the middle and eastern Qinling Mountains, Funiu Mountains and southern Taihang Mountains and including the east of the Jialing River. Clade C with all 100% supports only including the Kangxian population in the western Qinling Mountains, which was previously included in *F. taihangnica*, was deeply diverged from Clade B.

3.2.2 Genetic distance The TN93 genetic distance on partial ND2 gene within each of *F. quadranus* (Clade A), *F. taihangnica* (Clade B) and *F. kangxianensis* (Clade C; Figure 3) is 0.0242 ± 0.0038 (0.0080–0.0343), 0.0132 ± 0.0026 (0–0.0258) and 0.0008 ± 0.0006 (0–0.0026), while the genetic distance of the interclades is 0.1687 ± 0.0157 (0.159–0.1796; Clade A vs. B), 0.1942 ± 0.0189 (0.1833–0.2040; Clade A vs. C) and 0.0902 ± 0.0107 (0.0826–0.0953; Clade B vs. C).

3.3 Taxonomic conclusion

The evidences from the molecular and morphological analyses indicated that the Kangxian population, which was previously included in *F. taihangnica*, was discernibly different from the other populations of *F. taihangnica* and *F. quadranus*. This supports the hypothesis that the Kangxian population represents a distinct species, described herein as new:

Feirana kangxianensis sp. nov.

Paa quadrana: Li, Li, Wang, Zhang. 2000. Sichuan J Zool, 19(2): 75 (Kangxian, Gansu).

Feirana taihangnica: Wang, Jiang, Xie, Cheng, Dubois, Liang, Wagner. 2009. Zool Sci, 26: 505 (Kangxian, Gansu).

Holotype: CIB 2010091137, adult male (Figure 4), was collected in Douba Town (33°14.434′ N 105°24.048′ E, 1600 m alt.) in Kangxian County, Gansu, China on September 11, 2010 by Junhua HU and Xin YANG.

Allotype: CIB 2010091146, adult female, same time and locality as the holotype.

Paratypes: 56 adult males, 45 adult females and 66 tadpoles: CIB 2010091101-12, 16-26, 29, 31-36, 38-45, 47-52 (30♂♂, 14♀♀), CIB 2010091201, 03-14, 18-20, 23-24 (4♂♂, 13♀♀), and CIB-Kangxiankd-20100912 (tadpoles) were collected together with the holotype; CIB2010091305, 14-17, 20 (2♂♂, 4♀♀), collected in Yangba Town (33°04.153′N 105°46.535′E, 700m alt.), Kangxian County, Gansu on September 13, 2010 by Junhua HU and Xin YANG. CIB Kangxian 01-30, 32 (19♂♂, 12♀♀) were collected by Bin WANG and Rongchuan XIONG on August 26, 2008 at the same locality as the holotype.

Diagnosis: **(1)** The adult males of the new species *F. kangxianensis* possess the keratinized nuptial spines on their thumb, which were not found in the males of *F. taihangnica* and *F. quadranus*. **(2)** Females: the ratios of UEW, INS, NSD and IPTL to SVL of *F. kangxianensis* were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$, Table 3), while the ratio of IOS to SVL of the new species was significantly larger than that of the latter two species ($P < 0.05$, Table 3); **(3)** Males: the ratios of INS, NSD, IPTW to SVL of the new species were significantly less than those of *F. taihangnica* and *F. quadranus* ($P < 0.05$, Table 3), while the ratio of HL to SVL of the former was significantly larger than that of the latter, and the ratio of HW to SVL of *F. kangxianensis* was significantly larger than that of *F. taihangnica* but less than that of *F. quadranus*, the ratio of OPTL to SVL of *F. kangxianensis* was significantly less than that of *F. taihangnica* but larger than that of *F. quadranus* ($P < 0.05$, Table 3).

Description of holotype: Large in size (SVL 81.08 mm) and body robust; head medium, wider than long (HW 32.00 mm, HL 27.22 mm), its top flat. Kanthus rostralis indistinct and rounded; loreal region concave and obliquely flared; snout rounded and protruding, its length (SL 10.84 mm) longer than horizontal diameter of eye (ED 7.86 mm); interorbital space flat with a white point, less (IOS 4.80 mm) than width of upper eyelid (UEW 7.16 mm) and internasal space (INS 7.06 mm); distance between anterior corners of eyes (AED 12.60 mm) 0.62 times of the distance between posterior corners of eyes (PED 20.34 mm); nostrils oval with a small tubercle on the lateral-posterior of the flap of skin around the nostril, larger to tip of snout (NSD 6.00 mm) than to eye (NED 4.64 mm); pupil diamond-shaped; Tympanum distinct (TD 3.34 mm) and oval, about half of eye diameter; tympanum-eye distance (TED 4.22 mm) larger than tympanum diameter; a very strong and long supratympanic fold from the posterior of eye, and then oblique downward throughout the upper edge of the tympanic, directly to the shoulder; tongue large and oval in shape, deeply notched posterior; vomerine teeth distinct, arranged between choanae.

Fore limbs short but not broad; forearm little enlarged; fingers with slight dermal fringe, free of web; relative length of fingers: III>IV>I>II; finger tips rounded but not dilated; subarticular tubercles developed, supernumerary tubercles absent, no circummarginal groove or lateroventral groove; prepollex distinct, inner metacarpal tubercles larger and protrude than outer and middle ones, all found compressed.

Hind limbs long and stout, tibiotarsal articulation of adpressed limb reaching eye; toes long with slight dilated tips, relative length of toes: IV>III>V>II>I; thigh shorter than tibia (TiL 41.88 mm, TL 43.90 mm), heels overlapped when hind limbs are flexed and held perpendicular to body; toes fully webbed between; free sides of the first and fifth toes with developed dermal fringe, with the former connected with inner metatarsal tubercle and the latter reaching posterior one third of metatarsal; subarticular tubercles large and very distinct; inner metatarsal tubercle large and long, outer metatarsal tubercle absent, without tarsal folds.

Dorsum of head smooth; small granules scattered on lateral head, dorsal side of limbs, and dorsal and upper lateral body, middle large longitudinal tubercles present on upper lateral body; the posterior one third part of body dorsum covered with small but very dense white granules, the closer to the anal, the greater the granules are. Black horny spines found on the granules. Anus not very bulged, inner side of anal pore with the same granules; dorsal-lateral fold absent, but where were occupied by longitudinal tubercles; ventral side of head, limbs and body smooth.

Nuptial pads and nuptial spines only present on the prepollex and first finger, including three sites, one on the prepollex, the others around the first finger; found with no vocal sac and opening of it; lineae masculinae absent.

Color of holotype in life: Dorsal and lateral parts of limbs, head and body near to lemon yellow with black brown patches on body and head, hands and fingers, and foots and toes while wide stripes on limbs; ventral side of limbs, head and body grayish white, with thick gray spots on throat and chest, the former much dense.

Upper lip is almost uniform thick gray while lower lip is grayish white with thick gray spots. Posterior part of thigh is marbled in thick gray. Small gray spots found on webs near to toes.

Color of holotype in formalin: Body faded to gray; the lemon yellow faded to grayish white. Gray spots on throats and chest became more distinct after being kept in the preservative.

Measurements of holotype (mm): SVL 81.08, HL 27.22, HW 32.00, VRL 2.94, SL 10.84, ED 7.86, UEW 7.16, IOS 4.80, INS 7.06, NSD 6.00, NED 4.64, AED 12.60, PED 20.34, TD 3.34, TED 4.22, LAHL 35.86, HaL 21.26, IPTL 4.24, IPTW 2.66, OPTL 3.50, OPTW 1.68, TiL 41.88, TL 43.90, TW 15.00, TFL 64.98, FL 44.44, IML 5.58, and IMW 1.18.

Variation: The 55 adult males of *F. kangxianensis* differed in distribution of nuptial spines on the first finger and prepollex. Of them, eight possessed three clusters of the nuptial spines on the thumb like the holotype, seven possessed two clusters, and the rest had only one cluster. Of some individuals, body was light brown rather than dark brown as on the holotype. Some individuals were characterized with stripes on the surface of limbs, but dorsal and ventral body was found not like that of the holotype. The anal region of some adult males was smooth. The differences between the measurements of males and females are summarized in Table 6.

Tadpole: 66 tadpoles at 27–28 stages (Gosner, 1960) were collected together with the holotype, belonging to the Acosmanura type. Dorsal part of body thick gray with brown yellowish marbles, dorsal skin of tail with yellow patches, almost formed a stripe (Figure 5); tail end blunt; lower labial papillae arranged in two rows, lower corners of mouth with additional papillae; their keratodont formula containing five types:II: 5+5/1+1:II (40 tadpoles), II: 6+6/1+1:II (22 tadpoles), II: 5+6/1+1:II (1 tadpole),II: 6+6/1+1:II (1 tadpole), and II:5+5/1+1:I:1+1 (2 tadpoles). The measurements based on 20 tadpoles are summarized in Table 7.

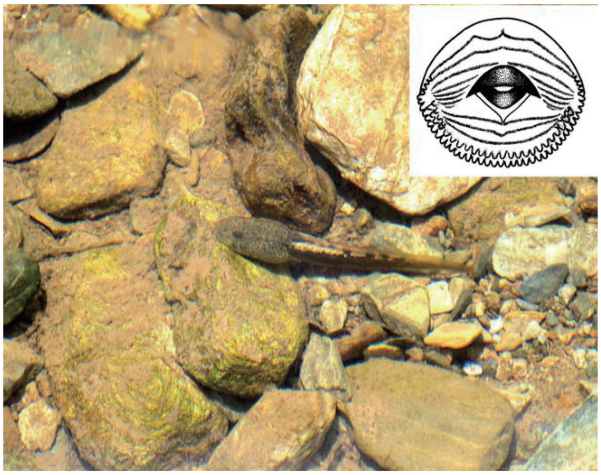

Figure 5 Tadpole in its habitat and keratodont formula of the new species *F. kangxianensis*

Eggs: We did not find eggs in field. Some characters of eggs were obtained through dissecting one adult female (CIB20091222), it contained 782 eggs with distinct animal pole in color of thick gray occupying about one third of a egg while plant pole in color of grayish white. The egg's diameter is 3.00±0.15 mm (n = 5; 2.98, 2.76, 3.00, 3.14, 3.12 mm).

Conservation: The streams where *F. kangxianensis* distributes flow through many villages, indicating that the frogs are possibly influenced by the villagers. In the field work, we simultaneously asked the villagers whether they had ever caught or would want to catch the frogs. Most of them (about 90%) answered yes, and some expressed they had done it recently. This means that the new species *F. kangxianensis* needs emergent protection and some protection measures should be applied in the area in the future.

Ecological notes: The new species is currently known only from its type locality, that is, the Kangxian County, Gansu, and it was found in two streams in the area so far, the Yangba River and Douba River. Adults are primarily found under stones in water of the streams. Larvae are adapted to the streams and possibly need 2–3 years to complete their metamorphosis. Most of specimens including holotype and allotype were collected in the

Table 6 Twenty eight measurements (ranges, followed by means ± SD, in mm) and the ratio of each measurement to the SVL (%) of *F. kangxianensis* sp. nov., *F. taihangnica*, and *F. quadranus*.

	F. kangxianensis		*F. taihangnica*		*F. quadranus*	
	Males (n=55)	Females (n=45)	Males (n=105)	Females (n=103)	Males (n=146)	Females (n=117)
SVL	55.94−87.40	54.60−101.10	51.26−90.50	49.98−103.40	53.50−102.86	45.66−105.98
	70.10±8.42	76.24±11.82	69.78±9.12	77.51±12.36	75.78±9.60	79.60±13.40
HL	18.24−29.14	18.60−31.58	12.30−30.02	14.75−30.00	13.49−32.26	15.25−33.12
	23.70±2.58	24.96±3.33	20.12±2.58	21.69±3.01	20.86±2.85	22.06±3.68
	33.81	32.73	28.83	27.99	27.53	27.72
HW	21.30−34.66	20.54−38.68	18.84−36.08	18.74−37.02	20.78−41.34	16.76−39.52
	27.36±3.55	29.41±4.29	26.48±3.74	29.01±4.28	29.13±4.11	30.04±4.31
	39.03	38.57	37.94	37.43	38.43	37.74
VRL	1.36−3.76	1.96−4.00	1.78−4.44	1.90−5.00	1.56−4.62	1.46−4.78
	2.75±0.44	2.79±0.44	2.96±0.59	3.23±0.66	2.88±0.49	2.94±0.66
	3.93	3.66	4.24	4.17	3.8	3.69
SL	6.18−11.56	8.30−12.90	7.46−14.40	7.56−17.78	7.50−15.32	7.04−15.75
	9.86±1.08	10.6±1.16	11.16±1.68	12.13±1.92	11.45±1.72	11.90±1.86
	14.06	13.91	15.99	15.65	15.11	14.95
ED	5.34−9.16	6.06−9.16	2.34−11.30	5.14−11.64	5.30−12.80	6.24−12.16
	7.00±0.68	7.28±0.78	7.71±1.36	8.10±1.37	8.68±1.27	8.79±1.32
	9.99	9.54	11.05	10.46	11.45	11.04
UEW	1.92−7.28	4.22−8.74	4.32−9.50	4.32−9.50	4.00−9.95	4.14−9.95
	5.88±0.90	6±1.02	6.71±1.20	7.23±1.25	7.36±1.13	7.45±1.19
	8.39	7.87	9.62	9.33	9.71	9.36
IOS	3.08−6.84	3.24−7.04	3.16−5.74	2.90−6.94	3.18−5.68	1.90−6.68
	4.49±0.74	5.06±0.94	4.19±0.53	4.34±0.67	4.33±0.49	4.47±0.66
	6.41	6.64	6.01	5.59	5.71	5.61
INS	5.04−7.88	5.38−8.74	4.82−10.32	5.28−10.68	5.00−10.10	4.72−9.58
	6.54±0.51	6.90±0.75	7.65±1.07	8.20±1.25	7.21±0.95	7.55±0.98
	9.33	9.05	10.96	10.58	9.52	9.48
NSD	3.06−7.40	4.80−8.00	4.32−9.52	4.66−11.70	4.50−10.85	4.20−10.17
	5.80±0.77	6.08±0.71	7.32±1.25	7.91±1.47	7.00±1.40	7.20±1.35
	8.27	7.97	10.5	10.21	9.23	9.05
NED	2.72−5.58	3.08−9.72	2.78−4.92	2.96−5.68	3.00−5.96	2.84−5.57
	4.22±0.65	4.58±1.01	3.80±0.47	4.17±0.61	4.25±0.51	4.45±0.66
	6.02	6	5.45	5.38	5.61	5.59
AED	8.36−13.96	5.50−14.74	6.68−15.58	7.84−15.76	8.30−17.45	7.70−15.33
	10.81±1.82	11.77±1.84	11.28±1.60	12.08±1.68	11.98±1.45	12.22±1.52
	15.68	15.43	16.16	15.59	15.81	15.35
PED	10.24−20.76	12.40−22.84	12.14−23.48	12.12−24.08	13.52−26.17	12.12−25.25
	16.51±2.17	17.84±2.46	17.63±2.49	18.73±2.71	19.51±2.55	19.90±2.71
	23.56	23.39	25.26	24.17	25.74	25
TD	2.06−6.30	2.50−5.30	2.38−5.60	2.18−6.70	2.33−5.86	2.20−5.57
	3.56±0.66	3.75±0.67	3.73±0.77	3.80±0.98	3.80±0.78	3.83±0.67
	5.08	4.91	5.35	4.9	5.01	4.81
TED	2.54−5.68	1.60−5.88	2.18−5.24	2.14−5.44	1.91−5.17	1.88−6.03
	3.81±0.75	4.08±0.98	3.44±0.58	3.87±0.65	3.53±0.67	3.80±0.71
	5.43	5.35	4.93	5	4.66	4.78
LAHL	23.92−38.64	22.92−39.50	21.08−42.20	22.10−47.74	24.59−53.39	19.40−49.05
	29.87±6.52	32.45±4.58	32.30±4.68	35.09±5.25	37.07±5.33	37.44±5.95
	42.61	42.56	46.29	45.27	48.92	47.04
HaL	13.72−29.10	14.80−28.90	12.86−28.30	12.94−28.42	13.02−33.72	11.36−31.67
	18.47±2.65	19.78±2.61	20.29±3.05	21.97±3.64	22.61±3.65	23.16±4.01
	26.35	25.94	29.08	28.35	29.84	29.09
IPTL	2.74−5.50	3.38−5.10	2.24−6.26	2.52−6.88	2.78−7.71	2.60−7.01
	4.00±0.62	4.17±0.40	4.42±0.93	4.73±0.95	4.96±0.92	4.97±0.98
	5.7	5.47	6.33	6.1	6.54	6.24
IPTW	1.08−3.68	2.00−3.30	1.44−5.28	1.72−5.28	1.76−6.09	1.08−4.85
	2.56±0.51	2.64±0.33	3.14±0.77	3.41±0.78	3.26±0.74	3.23±0.79
	3.65	3.46	4.5	4.39	4.3	4.06

(Continued Table 6)

	F. kangxianensis		*F. taihangnica*		*F. quadranus*	
	Males (n=55)	Females (n=45)	Males (n=105)	Females (n=103)	Males (n=146)	Females (n=117)
OPTL	2.46−4.74	2.50−5.20	1.88−7.10	2.36−6.64	2.26−6.88	2.16−6.45
	3.62±0.41	3.87±0.61	4.17±0.94	4.45±0.97	4.64±0.90	4.59±0.96
	5.17	5.08	5.98	5.74	6.12	5.76
OPTW	1.16−2.18	1.08−2.64	0.80−4.10	0.98−3.20	0.98−8.00	1.10−3.74
	1.64±0.23	1.80±0.27	1.71±0.41	1.81±0.42	2.11±0.61	2.07±0.42
	2.34	2.36	2.45	2.34	2.79	2.6
TiL	26.24−45.76	28.70−46.62	25.32−50.32	24.26−52.96	29.58−59.56	22.10−56.15
	35.99±4.79	38.26±5.37	37.38±5.77	40.29±6.36	41.65±5.98	42.06±6.91
	51.34	50.17	53.56	51.98	54.96	52.84
TL	28.90−46.68	30.00−49.22	27.36−49.05	26.08−53.78	31.48−63.50	24.72−56.49
	38.12±5.02	40.22±5.57	39.33±5.43	42.29±6.19	44.26±5.56	44.82±6.44
	54.37	52.76	56.37	54.48	58.41	56.31
TW	10.04-17.66	9.80−25.36	7.66−17.97	7.86−18.70	8.50−23.00	6.46−76.08
	13.08±1.89	13.98±2.75	13.01±2.30	14.01±2.59	13.71±2.19	14.36±6.32
	18.66	18.34	2.3	18.07	18.09	18.04
TFL	39.74-67.24	40.80−69.00	40.08−72.48	39.52−79.42	42.00−89.14	32.96−83.36
	53.56±7.55	57.28±8.47	57.27±7.82	61.84±8.98	64.45±8.37	64.93±10.16
	76.41	75.13	82.07	79.78	85.04	81.58
FL	27.14−43.72	27.72−47.06	27.12−49.52	26.44−54.32	29.46−60.31	22.30−57.47
	35.98±4.27	38.74±5.15	39.03±5.57	42.18±6.49	43.28±6.09	43.58±7.25
	51.33	50.81	55.93	54.42	57.12	54.75
IML	3.66−6.66	3.70−7.04	2.76−7.54	3.14−7.76	3.60−9.65	3.12−9.20
	5.24±0.67	5.64±0.84	5.25±1.11	5.72±1.13	5.99±1.09	6.16±1.18
	7.47	7.39	7.52	7.38	7.91	7.73
IMW	1.12−2.66	1.26−2.56	0.80−4.82	0.92−3.80	0.98−3.58	1.08−3.03
	1.65±0.3	1.79±0.32	1.81±0.54	1.91±0.48	2.08±0.44	2.05±0.46
	2.35	2.35	2.59	2.46	2.75	2.57

Table 7 Measurements (mm, means ± SD) of tadpoles of *F. kangxianensis* (at stages 27–28, Gosner, 1960)

Total length	Snout length	Head and body length	Body height	Body width
35.76−58.42	3.40−5.30	12.98−18.22	4.86−9.18	6.66−11.48
44.74±6.43	4.45±0.46	15.52±1.44	6.81±1.20	8.62±1.34
Mouth width	**Interorbital distance**	**Tail muscle width**	**Tail length**	**Tail height**
3.90−6.50	3.30−4.80	1.90−4.00	23.40−39.06	5.98−8.44
5.29±0.62	3.96±0.40	2.67±0.70	29.93±4.10	7.04±0.76

streams at night (06:00–12:00 pm) with water pH 8.8 and water temperature 14–20 °C. It's also easy to find them, for an example, in a sunny day (12 Sep., 2010), we found over 50 frogs staying under sunlight (with air temperature 20 °C, water temperature 18–22 °C) in a small branch (about 2000 m long, with little water) of the Douba River, at an elevation from 1740 m to 1962 m.

Our field survey in the Douba River showed that the vertical distribution of this new species ranged from 780 m to 1962 m, reaching the head water of the River. The segment of the river below altitude 1740 m was found with temperate broad–leaved deciduous forest, while the river above 1740 m with grasslands with small patches of planted fir trees. Most of the adults and tadpoles of this species were found in the places around 1600 m and above 1740 m (Figure 6).

Etymology: Latinized specific name of the new species is from the locality where the new species was firstly found.

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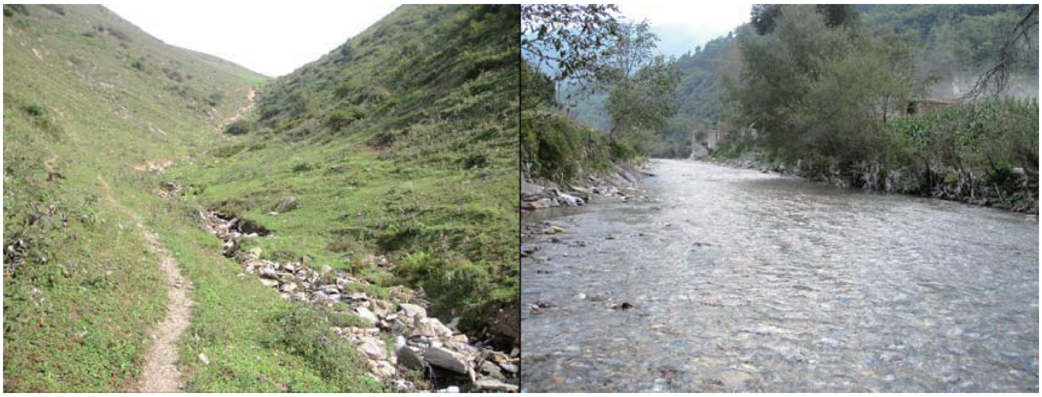

Figure 6 The habitats of *F. kangxianensis* in its type locality. The left is in the upper stream (above 1740 m) with grassland on both sides, and the right is in the down stream (below 1600 m) of 4–15 m wide.

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Appendix

List of specimens measured The morphologically examined and measured voucher specimens are deposited at the Chengdu Institute of Biology, Chinese Academy of Sciences (CIB), and the College of Life Sciences, Henan Normal University (HNNU). Specimens with "*" were collected and measured in this study, and the others were retrieved from Wang *et al.* (2007).

***F. kangxianensis*:**

Males: CIB 2010091101*, 2010091103*, 2010091105*, 2010091107–09*, 2010091111*, 2010091116*, 2010091117*, 2010091119*, 2010091121–26*, 2010091133–38*, 2010091141–45*, 2010091147*, 2010091149*, 2010091150–52*, 2010091201*, 2010091203*, 2010091206*, 2010091214*, 2010091320*, 2010091315*, Kangxian05*, Kangxian 06*, Kangxian 11*, Kangxian 10*, Kangxian 13–15*, Kangxian 17–19*, Kangxian 21–25*, Kangxian 28*, Kangxian 30*, Kangxian 32*.

Females: CIB 2010091102*, 2010091104*, 2010091106*, 2010091110*, 2010091112*, 2010091118*, 2010091120*, 2010091129*, 2010091131*, 2010091132*, 2010091140*, 2010091144*, 2010091146*, 2010091148*, 2010091204*, 2010091205*, 2010091207–09*, 2010091212*, 2010091213*, 2010091216*, 2010091218–20*, 2010091223–24*, 2010091305*, 2010091314*, 2010091316*, 2010091317*, Kangxian 01–04*, Kangxian 07–09*, Kangxian 12*, Kangxian 16*, Kangxian 20*, Kangxian 26*, Kangxian 29*.

***F. taihangnica*:**

Males: CIB 20060290–291, 20060296, 20060301–02, 20060318, 20060331–32, 20060335–36, 20060338, 56609, 56611–15, 56618–21, 56624, 56628, 56630, 56631, 56633, 56636, 56641, 56643, 56645–56650, 56652, 56654, 56656, 56657, 56660–56663, 56667, 56668, 56673, 56683–56687, 56722, 56723, Banfangzi 3*, Banfangzi 6*, Banfangzi 7*, Beigou 1*, Beigou 3*, Huoditang 2*, Huoditang 4*, Huoditang 5*, Qianyouhe 1*, Taibai 01–02*, Taibai 04–05*, Taibai 07*, Taibai 10*, Taibai 13*, Taibai 15–17*, Taibai 19*, Taibai 20–22*, Taibai 27–28*, Taibai (5)–(7), Taibai 9, Xunyangba 3*, Xunyangba 5–6*.

HNNU 207009, 404001, 404050, 405008, 405010, 407006, 407023, 407025, 407027, 504001, 504003, 504005, 504008–009, 508002, 508009, 508060, 508v058, 508v061.

Females: CIB 20060297, 20060299–300, 20060306, 20060320–321, 20060325–328, 20060337,

56608, 56610, 56616–17, 56622–23, 56625–27, 56629, 56632, 56634–35, 56637–40, 56642, 56644, 56651, 56653, 56655, 56664–66, 56668–70, 56677, 56679, 56681–82, 56701, 56710, 56721, Banfangzi 1*, Banfangzi 2*, Banfangzi 4–5*, Banfangzi 8–9*, Beigou 2*, Beigou 4–5*, Dudumen 1–3*, Laoxiancheng 9*, Laoxiancheng 20*, Huanghualing 1*, Qianyouhe 3*, Taibai 03*, Taibai 08–12*, Taibai 14*, Taibai 16*, Taibai 18*, Taibai 24–26*, Taibai (2)–(3), Taibai (8), Xunyangba 2*, Xunyangba 4*, Xunyangba 8*, Xunyangba 10*.

HNNU 210088, 404016–17, 404021, 404054, 405003, 405006, 405024–25, 407003, 407005, 407029–30, 47121, 47125, 508007, 508052–53, 508059.

***F. quadranus*:**

Males: CIB 20060644–46, 20060648, 20060650, 2010091711–14*, 2010091718*, 2010091720*, 2010101001*, 2010101003*, 2010101006*, 56143, 56146, 56152, 56153, 56157, 56167, 56169, 56171, 56173, 56174, 56176, 56179, 56183, 56184, 56186, 56195–56198, 56200, 56204, 56206, 56207, 56213, 56216, 56218, 56221, 56222, 56223, 56225, 56227, 56234, 56236, 56728, 56729, 56730, 56732–56736, 56738, 56739, 56740, 56741, 56743, 56744, 56745, 56748, 56749, 56750, 56754, 56762, 56763, 56764, 56765, 56767, 56771, 56779, 56792, 56793, 56794, 56796, 56806, 56808, 56809, 56811, 56815, 56816, 56818, 56819, 56820, 56827, 56829, 56830, 56831, 56832, 56834, 56835, 56839, 56843, 56848, 56849, 56850, 56851, 56852, 56856, 571328, 571330, 571358, 571363, 571374, 571378, 571380, 571382, 571388, 571390, 571535, 571790, 571792, 571800, 571805, 571810–571812, 571829, 571831, 571843–571845, 571856, 571858, 571861, 571862, 571875, 571946, 571982, 572262, 572267, 572269, 572277, 572278, Danangou 3*, Huoditang 1*, Qianyouhe 2*, Qianyouhe 4*, Xunyangba 7*, Xunyangba 9*.

Females: CIB 20060647, 20060649, 2010091715−17*, 2010091719*, 2010101002*, 2010101004−05*, 2010101007−08*, 56144, 56147, 56148, 56151, 56154, 56156, 56158, 56159, 56177, 56185, 56190, 56191, 56211, 56212, 56214, 56215, 56217, 56226, 56228−30, 56233, 56235, 56737, 56746, 56751−56753, 56755, 56756, 56766, 56768, 56770, 56777, 56778, 56780, 56781, 56782, 56795, 56797−05, 56807, 56810, 56812−14, 56817, 56821−26, 56833, 56836−38, 56840−42, 56844, 56845, 56847, 56853−55, 56857−60, 571791, 571793, 571795, 571796, 571802, 571804, 571806, 571807, 571840, 571841, 571842, 571846, 571857, 572236, 572264, 572270, 572272, 572273, 572276. Danangou 1*, Danangou 2*, Qianyouhe 1*, Qianyouhe 3*, Qianyouhe 5*, Qianyouhe 6*, Qianyouhe 8−10*, Xunyangba 1*, Xunyangba 11*.